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Mercury, Monomethyl Mercury, and Dissolved Organic Carbon Concentrations in Surface Water Entering and Exiting Constructed Wetlands Treated with Metal-Based Coagulants, Twitchell Island, California

Data Series 950

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photographs taken by Tamara Kraus, U.S. Geological Survey.
Top Left: Coagulation system designed and built by Bachand and Associates.
Bottom Left: Water samples collected from the inlets of the experimental wetland cells: 6 (control, not treated), 5 (iron treatment) and 4 (aluminum treatment).
Right: One of the constructed wetlands cells, Twitchell Island, California.

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[1]U.S. Geological Survey California Water Science Center.

[2]Bachand and Associates, Davis, California.

[3]University of California, Davis, California.

[4]U.S. Geological Survey Wisconsin Water Science Center.

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U.S. Department of the Interior
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Conversion Factors

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in^3)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as °F = (1.8 × °C) + 32.

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

DOC	dissolved organic carbon
EPA	U.S. Environmental Protection Agency
Hg	mercury
HRT	hydraulic residence time
KHP	potassium hydrogen phthalate
LRL	laboratory reporting limit
MDL	method detection limit
MeHg	monomethyl mercury
MeHg-F	monomethyl mercury in filtered water
MeHg-P	monomethyl mercury in suspended particulates
PETG	polyethylene terephthalate glycol-modified
RPD	relative percent difference
SD	standard deviation
SRM	standard reference material
THg	total mercury, sum of filtered and particulate measurements
THg-F	total mercury in filtered water
THg-P	total mercury in suspended particulates

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Abstract

Coagulation with metal-based salts is a practice commonly employed by drinking-water utilities to decrease particle and dissolved organic carbon concentrations in water. In addition to decreasing dissolved organic carbon concentrations, the effectiveness of iron- and aluminum-based coagulants for decreasing dissolved concentrations both of inorganic and monomethyl mercury in water was demonstrated in laboratory studies that used agricultural drainage water from the Sacramento–San Joaquin Delta of California. To test the effectiveness of this approach at the field scale, nine 15-by-40-meter wetland cells were constructed on Twitchell Island that received untreated water from island drainage canals (control) or drainage water treated with polyaluminum chloride or ferric sulfate coagulants. Surface-water samples were collected approximately monthly during November 2012–September 2013 from the inlets and outlets of the wetland cells and then analyzed by the U.S. Geological Survey for total concentrations of mercury and monomethyl mercury in filtered (less than 0.3 micrometers) and suspended-particulate fractions and for concentrations of dissolved organic carbon.

In the control wetland cells, total mercury concentrations in filtered water samples ranged from 0.94 to 2.47 nanograms per liter (ng/L) at the control inlets and from 0.84 to 2.63 ng/L at the control outlets, and particulate total mercury concentrations in water ranged from 0.27 to 1.49 ng/L at the control inlets and from 0.17 to 1.11 ng/L at the control outlets. Monomethyl mercury concentrations in filtered water ranged from 0.16 to 0.88 ng/L at the control inlets and from 0.13 to 1.30 ng/L at the control outlets; particulate monomethyl mercury concentrations in water ranged from 0.03 to 0.24 ng/L at the control inlets and from 0.03 to 0.23 ng/L at the control outlets. Dissolved organic carbon concentrations in water ranged from 7.9 to 26.7 milligrams per liter at the control inlets and from 8.5 to 28.0 milligrams per liter at the control outlets.

Following coagulation, but prior to passage through the wetland cells, coagulation treatments transferred dissolved mercury and carbon to the particulate fraction relative to untreated source water: at the wetland cell inlets, the coagulation treatments decreased concentrations of filtered total mercury by 59–76 percent, filtered monomethyl mercury by 40–70 percent, and dissolved organic carbon by 65–86 percent. Passage through the wetland cells decreased the particulate fraction of mercury in wetland cells that received coagulant-treated water. Changes in total mercury, monomethyl mercury, and dissolved organic carbon concentrations resulting from wetland passage varied both by treatment and season. Despite increased monomethyl mercury in the filtered fraction during wetland passage between March and August, the coagulation-wetland systems generally decreased total mercury (filtered plus particulate) and monomethyl mercury (filtered plus particulate) concentrations relative to source water. Coagulation—either alone or in association with constructed wetlands—could be an effective way to decrease concentrations of mercury and dissolved organic carbon in surface water as well as the bioavailability of mercury in the Sacramento–San Joaquin Delta.

Introduction

The Sacramento–San Joaquin Delta is a highly modified ecosystem that supplies drinking water to over 25 million Californians and irrigation water to millions of acres of farmland (Lund and others, 2010). In the delta, the reclamation of historic marshlands for agriculture by using levees and drainage canals resulted in land subsidence primarily due to oxidative loss of the organic soils, but also due to dewatering and compaction of the soil (California Department of Water

[1]U.S. Geological Survey California Water Science Center.

[2]Bachand and Associates, Davis, California.

[3]University of California, Davis, California.

[4]U.S. Geological Survey Wisconsin Water Science Center.

Resources, 1995; Deverel and others, 1998). In order to keep these subsided lands from reflooding, drainage water is continuously pumped off and released into surrounding delta channels. Because the drainage water contains high concentrations of dissolved organic carbon (DOC), it has been linked to elevated concentrations of DOC in the delta relative to the incoming river water, which is a concern for drinking-water quality (Fujii and others, 1998; Fleck and others, 2004, 2007; Kraus and others, 2008).

In addition to DOC, elevated mercury (Hg) concentrations in the delta are an ongoing regulatory issue, which is of particular concern in light of planned ecosystem restoration efforts that involve creation of wetlands known to enhance methylation rates (Conaway and others, 2008). The presence of Hg, particularly monomethyl mercury (MeHg), is a concern for both human and ecological health, because it is a neurotoxin that is biomagnified in the foodweb (Fitzgerald and others, 1998). In 2011, California's Central Valley Regional Water Quality Control Board established total maximum daily loads for MeHg in the delta and neighboring Yolo Bypass (Central Valley Regional Water Quality Control Board, 2010; Wood and others, 2010). These regulations were intended to spur management strategies that decrease MeHg export both from point and non-point sources, including agricultural lands and wetlands (McCord and Heim, 2015).

Dissolved organic carbon is considered a constituent of concern because during drinking-water treatment, a fraction of the DOC pool can react to form carcinogenic disinfection by-products (DBPs). The U.S. Environmental Protection Agency (EPA) regulates concentrations of DBPs in treated drinking water (Richardson and others, 2007). To reduce the formation of DBPs, water entering drinking-water treatment plants is commonly treated with metal-based salts that convert the DOC into colloidal and particulate forms, which can be removed from water by settling, filtration, or both (Bachand and others, 2010). Coagulation increases particle sizes, which results in higher settling velocities for suspended material (Duan and Gregory, 2003).

Because Hg is associated with suspended particulates and DOC (Lamborg and others, 2003; Ravichandran, 2004), it follows that Hg would be associated with the organo-metal precipitate, termed flocculate, and also be removed from solution in surface water by coagulation. The effectiveness of iron- and aluminum-based coagulants for decreasing concentrations both of inorganic Hg and MeHg in solution was demonstrated in laboratory studies that used agricultural drainage water from the central delta: dissolved concentrations of MeHg decreased by 80 percent, and inorganic Hg concentrations decreased by 97 percent, following coagulation (Henneberry and others, 2011; Henneberry, 2012). The in situ application of metal-based coagulants to decrease concentrations of Hg in solution, and, thereby, help reduce Hg export from managed systems, has been identified as a potentially effective management practice that requires further investigation (McCord and Heim, 2015).

Purpose and Scope

The purpose of this report is to present total Hg (THg, the sum of inorganic mercury and monomethyl mercury) and MeHg concentration data for filtered (dissolved, less than 0.3 micrometers) and suspended-particulate fractions of water along with DOC concentration data for surface-water samples collected from the inflow and outflow structures of 9 experimental-wetland cells (18 sites) constructed on Twitchell Island (fig. 1). Data in this report include samples collected approximately monthly during a 1-year period from November 2012 to September 2013.

The purpose of the project, of which this study is a part, was to assess the effectiveness 1) of treating delta-island drainage water with low concentrations of coagulants to decrease DOC and Hg concentrations in water, 2) of utilizing constructed wetlands to filter the resulting coagulated/flocculated material and to polish treated water prior to discharge into delta-channel water, and 3) of accumulating wetland biomass and flocculated material in wetlands, thereby mitigating subsidence. To this end, nine experimental 15-by-40-m wetland cells were constructed on Twitchell Island, a deeply subsided island in the central delta, which was once part of a tidal freshwater marsh that had peat soils up to several meters deep (Atwater and Belknap, 1980). Each wetland cell in this field experiment received either untreated drainage water, drainage water treated with iron sulfate, or drainage water treated with polyaluminum chloride. Following coagulation, the treated water passed through constructed wetlands designed to act as settling basins to retain the metal-organic flocculate that forms following coagulation. The use of constructed wetlands to retain the settled flocculate could not only reduce costs associated with construction of concrete basins and off-site disposal of the flocculate material, but also provide beneficial wetland habitat. Moreover, wetlands constructed on subsided islands in the central delta have been shown to effectively reverse subsidence (Miller and others, 2008; Miller and Fujii, 2011).

Laboratory experiments that used Twitchell Island drainage water to identify coagulant dosages and the stability of coprecipitated organic matter and ferric sulfate were published prior to the completion of this field study (Mourad, 2008; Henneberry, 2012; Henneberry and others, 2012). A subset of the data presented in this report (March–June, 2013) along with mercury bioaccumulation in fish (*Gambusia affinis*) collected from the nine wetland cells in July 2013 was published by Ackerman and others (2015). In addition, to meet the objectives of this project, the U.S. Geological Survey (USGS) and cooperators took field measurements and collected water, sediment, and soil samples to be used, for example, to examine treatment effects on pH, nutrient concentrations, disinfection by-product formation potential, metal concentrations, plant growth, sediment accretion, and sediment quality.

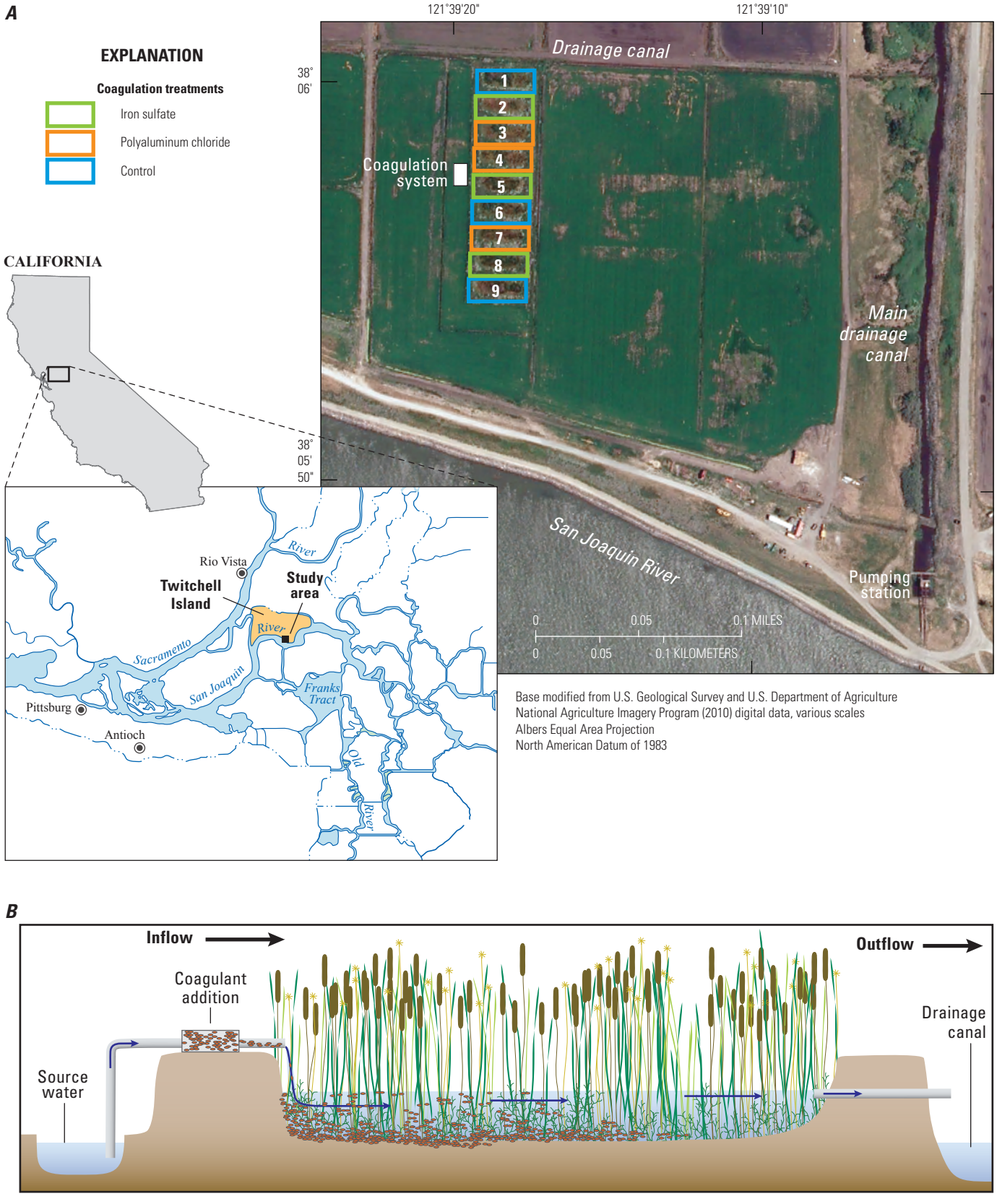

Figure 1. Location and design of experimental-wetland cells on Twitchell Island, California: *A*, aerial view of site design; *B*, wetland-cell design (not to scale).

Methods

The methods presented in this report are restricted to project activities related to evaluating the effectiveness of applying iron- and aluminum-based coagulants to Twitchell Island drainage water, followed by passage through constructed wetlands, which serve as settling basins, to reduce surface-water concentrations of THg, MeHg, and DOC.

Study Design

In 2008, nine experimental-wetlands cells were constructed on Twitchell Island, a subsided island in the central Sacramento–San Joaquin Delta (fig. 1). The nine wetland cells, each 15 meters (m) wide by 40 m long, included three treatments applied in a randomized complete block design (fig. 1). Three wetland cells received untreated source water and, thus, served as the control cells; three cells received source water that was treated with polyaluminum chloride (Kemira Water Solutions Inc., Finland); and three cells received water treated with ferric sulfate (Kemira Water Solutions Inc., Finland). Wetland-cell water depth was between 0.3 and 0.5 m (the mean was 0.4 m with a standard deviation, or SD, of 0.08 m among cells), and the hydraulic residence time (HRT) in the nine cells was 2–7 days, with a mean of 3.04 days and SD of 0.86 day, which can be expressed as 3.04 days ± 0.86. Hydraulic residence time was calculated by dividing the volume of water in each wetland cell by that cell's average flow rate (volume divided by time) and, thus, has units of time. Average flow rates were calculated for each day on the basis of 15-minute flow data measured at the wetland-cell inlets only when at least 93 of the 96 daily readings were recorded. This was done to ensure that equipment malfunction did not lead to flow-estimation errors. Average daily flow rates were then averaged for each week, which spanned Sunday through Saturday. This average weekly flow was used to calculate the HRT, which was expressed in days.

Source water for the wetland cells came from a nearby drainage canal, through which both moved irrigation water siphoned from the San Joaquin River and drainage water from surrounding fields. During the last 2 months, however, source water was diverted instead from the main drainage canal, which provides water to the pumping station (fig. 1). The canal network on Twitchell Island was designed to transport drainage water from the subsided island to the pumping station, which moves the water over the levee and into the San Joaquin River (Henneberry and others, 2011). The wetland cells were first flooded in July 2011. Following wetland construction and flooding, the wetlands vegetated naturally and were dominated by cattails (*Typha spp.*). During the first year of flooding, the coagulation system was constructed and tested intermittently. Starting on July 5, 2012, coagulation treatments were applied continuously, except for one 3-week period beginning October 16, 2012, when coagulation treatments were suspended to allow for equipment repair and replacement.

Coagulant dosages were adjusted to achieve between a 60 percent and 80 percent decrease in DOC concentrations. The appropriate coagulant dosages were estimated on the basis of laboratory-generated coagulation-dosage curves for Twitchell Island drainage water (Mourad, 2008; Henneberry, 2012) and were verified by using in-line, continuous measurement of pH and fluorescence of dissolved organic matter (Turner Designs, Sunnyvale, Calif.), a proxy for DOC concentration, at the inlets of cells 4–6. Weekly water samples for determination of DOC concentrations and other water-quality parameters were also collected by Bachand and Associates and the University of California at Davis. Because DOC concentrations in the source water varied over time, the coagulation dosages needed to be adjusted accordingly. To achieve a 60–80 percent decrease in DOC concentrations, the dosages for polyaluminum chloride ranged from 5 to 46 milligrams of aluminum per liter of water (mg Al/L) and dosages for ferric sulfate ranged from 13 to 31 milligrams of iron per liter water (mg Fe/L). Coagulants were injected into the pipes importing the source water and mixed thoroughly by using in-line static mixers prior to release into the wetland cells; thus, water collected at inlets reflected the water quality immediately following coagulant addition.

Sample Collection and Processing Methods

Water samples were collected approximately monthly at the inlet and outlet pipes of each of the nine wetland cells from November 2012 through September 2013. Water samples were collected in 2-liter (L) polyethylene terephthalate glycol-modified (PETG) Nalgene (Thermo Fischer Scientific, Waltham, Mass.) bottles by using clean techniques described in the USGS National Field Manual (Wilde and others, 2004). Bottles were stored immediately in the dark on ice for transport to the laboratory, and were processed within 36 hours of collection. In the laboratory, each sample was filtered to separate out the filterable fraction of mercury from the particulate fraction. The 2-L bottles were shaken vigorously and immediately poured into a clean, Teflon® 153 L per minute vacuum-filtration apparatus loaded with a 0.3 micrometer (µm) pore-size, pre-combusted, glass-fiber filter (model GF-7547 mm diameter, Advantec MFS, Dublin, Calif.; Lewis and Brigham, 2004). The volume of sample passed through each filter was recorded to the nearest milliliter. Filtered water samples were preserved with ultraclean hydrogen chloride (1.0 percent by volume) and stored in the dark at room temperature for no more than 6 months for mercury determination. The filters, which collected samples for assessment of THg and MeHg in suspended-particulate form, were immediately frozen at −20 degrees Celsius for no more than 6 months.

Analytical Methods

Total Mercury and Monomethyl Mercury Concentrations

Total Hg (the sum of inorganic mercury and monomethyl mercury) and MeHg concentrations in the filtered (THg-F and MeHg-F, respectively) and suspended-particulate fractions (THg-P and MeHg-P, respectively) of water were determined at the USGS Mercury Research Laboratory in Middleton, Wis. Filtered THg concentrations were determined according to EPA Method 1631 (U.S. Environmental Protection Agency, 2002). Total-mercury filters were digested in Aqua Regia prior to undergoing analysis according to EPA Method 1631, as described in Olund and others (2004). Filtered MeHg concentrations in water were determined by using standard distillation and ethylation procedures, as described by DeWild and others (2002). Monomethyl-mercury filters were extracted with methylene chloride prior to distillation and ethylation, as described by DeWild and others (2004). Method detection limits (MDLs) for filtered THg and MeHg are 0.04 nanograms per liter (ng/L). Particulate THg and MeHg MDLs are 0.059 ng/filter and 0.01 ng/filter, respectively. Because the particulate MDL was dependent on the volume of water filtered, detection limits as ng/L varied by sample.

Dissolved Organic Carbon Concentration

Dissolved organic carbon concentrations were determined by using high-temperature catalytic combustion on a total organic carbon analyzer (Model TOC-VCSH, Shimadzu Scientific Instruments, Columbia, Md.) at the USGS Organic Matter Research Laboratory in Sacramento, Calif., on samples filtered as described previously. Dissolved organic carbon concentrations in filtered water were determined according to a modified version of method EPA 415.3 (U.S. Environmental Protection Agency, 2005). The long-term MDL for DOC concentration was 0.03 milligrams per liter (mg/L), calculated by using EPA procedures in EPA Title 40 CFR Part 136, appendix B (U.S. Environmental Protection Agency, 1997). The laboratory reporting limit (LRL) of 0.3 mg/L was 10 times the MDL (0.03 mg/L) and was verified during analytical runs by using a low-concentration standard; the standard deviation of the long-term results of the low-concentration standard was less than 10 percent.

Quality-Assurance and Quality-Control Methods and Results

Mercury and DOC concentrations in surface water were validated against a set of quality-assurance and quality-control (QA/QC) criteria that included trip- and laboratory-blank samples, field replicates, laboratory duplicates, laboratory matrix-spike samples, ongoing precision and recovery samples, and standard and certified reference material.

Data-quality objectives of the project were met when 1) the mean of the trip-blank concentrations was less than the MDL; 2) the relative percent difference (RPD) of field replicates, laboratory duplicates, and reference materials was within 30 percent for THg-F and within 10 percent for MeHg-F and DOC; and 3) the matrix spike recoveries were within 30 percent for THg, 25 percent for MeHg, and 20 percent for DOC. The relative percent difference was calculated by dividing the absolute difference of two samples by the average of the two samples. Tables 1–4 present quality-assurance data for trip blanks, field replicates, matrix spikes, matrix-spike duplicates, certified reference materials, standard reference materials, ongoing precision and recovery samples, and laboratory duplicates for Hg and DOC analyses.

Total Mercury and Monomethyl Mercury

Type 1 ultrapure water (Barnstead, Thermo Scientific) was used for “trip-blank” samples, and these samples were brought to the field site in 2-L PETG bottles, after which they underwent laboratory processing procedures described previously. For THg-P and MeHg-P, all trip blanks were less than the MDLs. One trip blank was greater than the MDL for MeHg-F, however, and seven trip blanks were greater than the MDL for THg-F (table 1). The high value of 0.18 ng/L for a MeHg-F trip blank was attributed either to field or to laboratory equipment contamination. Although concentrations measured in seven THg-F trip blanks (0.04–0.07 ng/L) were greater than the MDL of 0.04 ng/L, the concentrations were notably less than THg-F measured in surface-water samples during the study (0.23–2.63 ng/L, table 5).

Ten field replicates were collected and processed in the same manner as the surface-water samples for the study to confirm the reproducibility of field and laboratory procedures. The mean RPD was less than 7 percent both for THg-F and for MeHg-F measurements (table 2). There were some relatively high RPDs for THg-P and MeHg-P measurements. The accuracy and precision of THg and MeHg measurements were within 10 percent, as indicated by ongoing precision and recovery samples (reagent water with standard added), certified reference material, laboratory duplicates, matrix spikes, and matrix spike duplicates (table 3). The certified reference material for THg-P was IAEA-SL-1 (0.13 mg per kilogram, International Atomic Energy Agency, Vienna, Austria), and for MHg-P, it was SQC-1238 (10 µg per kilogram, R.T. Corporation, Laramie, Wyo.).

Table 1. Trip-blank data for surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy; month, day, year; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L; MDL for total mercury-particulate=0.059 ng/L; MDL for monomethyl mercury-particulate=0.01 ng/L; LRL for dissoved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
		Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Nov.	11/13/2012	0.04	<0.124	<0.04	<0.02	0.1
Dec.	12/11/2012	0.06	<0.130	<0.04	<0.04	0.1
Jan.	01/23/2013	0.06	<0.120	<0.04	<0.03	<0.03
Feb.	02/25/2013	<0.04	<0.124	<0.04	<0.02	0.09
Mar.	03/25/2013	<0.04	<0.123	<0.04	<0.02	<0.03
Apr.	04/23/2013	0.04	<0.118	0.18	<0.03	0.05
May	05/20/2013	0.04	<0.121	<0.04	<0.05	0.08
Jun.	06/24/2013	<0.04	<0.119	<0.04	<0.04	0.11
Jul.	07/22/2013	0.07	<0.244	<0.04	<0.04	0.09
Sep.	09/03/2013	0.04	<0.138	<0.04	<0.02	0.06

Table 2. Relative percent difference of field-replicate and study water-sample data for surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon in experimental-wetland cells, Twitchell Island, California, November 2012–September 2013.

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-Out, polyaluminum chloride treated outlet water; Co-Out, untreated control outlet water; C*x*, wetland cell number; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month, day, year; na, not applicable; ng/L, nanograms per liter; Rep, replicate sample; RPD, relative percent difference. The LRL for dissolved organic carbon=0.3 mg/L; MDL for monomethyl mercury-particulate=0.01 ng/L; MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L; MDL for total mercury-particulate=0.059 ng/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury, filtered			Total mercury, particulate			Monomethyl mercury, filtered		
			Rep (ng/L)	Sample (ng/L)	RPD	Rep (ng/L)	Sample (ng/L)	RPD	Rep (ng/L)	Sample (ng/L)	RPD
Control samples											
C6-Co-Out-Jan	01/22/2013	380557121391901	1.26	1.26	**0.00**	0.24	0.25	**5.74**	0.14	0.14	**0.00**
C9-Co-Out-Feb	02/25/2013	380555121391901	1.43	1.39	**2.84**	0.27	0.27	**0.37**	0.23	0.27	**16.00**
Polyaluminum chloride treated samples											
C4-Al-Out-Nov	11/13/2012	na	0.22	0.24	**8.70**	0.13	0.09	**34.55**	0.04	0.04	**0.00**
C4-Al-Out-Dec	12/11/2012	na	0.43	0.44	**2.30**	0.18	0.23	**22.77**	0.11	0.12	**8.70**
C3-Al-Out-May	05/20/2013	na	0.72	0.72	**0.00**	0.15	0.23	**38.32**	0.34	0.32	**6.06**
C8-Al-Out-Jun	06/25/2013	na	0.77	0.79	**2.56**	0.35	0.43	**19.92**	0.41	0.39	**5.00**
C8-Al-Out-Jul	07/22/2013	na	0.67	0.62	**7.75**	0.26	0.18	**33.86**	0.28	0.28	**0.00**
Ferric sulfate treated samples											
C5-Fe-Out-Mar	03/26/2013	na	0.82	0.95	**14.69**	0.60	0.70	**14.67**	0.19	0.18	**5.41**
C7-Fe-Out-Apr	04/23/2013	na	0.82	0.86	**4.76**	0.94	0.73	**24.54**	0.22	0.24	**8.70**
C5-Fe-Out-Sep	09/03/2013	na	0.51	0.54	**5.71**	0.48	0.40	**16.78**	0.14	0.12	**15.38**
MEAN			0.77	0.78	**4.93**	0.36	0.35	**21.15**	0.21	0.21	**6.52**

Table 2. Relative percent difference of field-replicate and study water-sample data for surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon in experimental-wetland cells, Twitchell Island, California, November 2012–September 2013.—Continued

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-Out, polyaluminum chloride treated outlet water; Co-Out, untreated control outlet water; C*x*, wetland cell number; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month, day, year; na, not applicable; ng/L, nanograms per liter; Rep, replicate sample; RPD, relative percent difference. The LRL for dissolved organic carbon=0.3 mg/L; MDL for monomethyl mercury-particulate=0.01 ng/L; MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L; MDL for total mercury-particulate=0.059 ng/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Monomethyl mercury, particulate			Dissolved organic carbon		
			Rep (ng/L)	Sample (ng/L)	RPD	Rep (mg/L)	Sample (mg/L)	RPD
Control samples								
C6-Co-Out-Jan	1/22/13	380557121391901	0.03	0.04	**28.57**	23.18	25.33	**8.86**
C9-Co-Out-Feb	2/25/13	380555121391901	0.04	0.03	**44.78**	24.68	24.89	**0.85**
Polyaluminum chloride treated samples								
C4-Al-Out-Nov	11/13/12	na	0.02	0.04	**53.97**	3.31	3.42	**3.27**
C4-Al-Out-Dec	12/11/12	na	0.04	0.05	**6.74**	11.78	10.36	**12.83**
C3-Al-Out-May	5/20/13	na	0.04	0.04	**2.67**	4.25	4.29	**0.94**
C8-Al-Out-Jun	6/25/13	na	0.08	0.08	**4.88**	4.18	4.17	**0.24**
C8-Al-Out-Jul	7/22/13	na	0.06	0.07	**14.17**	3.24	3.26	**0.62**
Ferric sulfate treated samples								
C5-Fe-Out-Mar	3/26/13	na	0.05	0.04	**18.95**	14.27	13.79	**3.42**
C7-Fe-Out-Apr	4/23/13	na	0.08	0.08	**2.50**	10.46	10.26	**1.93**
C5-Fe-Out-Sep	9/3/13	na	0.06	0.05	**24.30**	8.89	8.82	**0.84**
MEAN			0.05	0.05	**20.15**	10.82	10.86	**3.38**

Table 3. Laboratory quality-assurance data for surface-water concentrations of mercury and monomethyl mercury, Twitchell Island, California, November 2012–September 2013.

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. **Abbreviations:** n, number of samples; nd, not determined; ng/L, nanograms per liter; RPD, relative percent difference; SD, standard deviation. Method detection limit for filtered total mercury and monomethyl mercury is 0.04 ng/L]

Analysis	Certified reference material			Matrix spike			Matrix spike duplicate			Duplicate			Ongoing precision and recovery		
	n	mean recovery (percent)	SD	n	mean recovery (percent)	SD	n	RPD	SD	n	RPD	SD	n	mean recovery (percent)	SD
Total mercury, filtered	nd	nd	nd	28	101.3	3.9	nd	nd	nd	254	0.3	2.5	23	104.5	2.6
Total mercury, particulate	37	94.7	4.5	52	88.3	14.9	nd	nd	nd	46	3.8	7.3	nd	nd	nd
Monomethyl mercury, filtered	nd	nd	nd	69	104.5	9.1	34	8.7	6.9	nd	nd	nd	78	107.8	8.1
Monomethyl mercury, particulate	22	105.1	17.1	nd	nd	nd	nd	nd	nd	nd	nd	nd	66	104.7	7.3

Table 4. Laboratory quality-assurance data for surface-water concentrations of dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.

[All dissolved organic carbon analyses performed at U.S. Geological Survey, California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Caff, caffeine; ID, identification; KHP, potassium hydrogen phthalate; LRL, laboratory reporting level; mg/L, milligram per liter; n, number of samples; RPD, relative percent difference; RSD, relative standard deviation; SD, standard deviation; < , less than. Method detection limit for dissolved organic carbon is 0.03 mg/L of carbon; the LRL for dissolved organic carbon is 0.3 mg/L of carbon]

Analytical batch ID	Date (mm/dd/yyyy)	Blank		Standard reference material KHP			Standard reference material Caff			Matrix spike			Duplicate		
		n	Mean concentration (mg/L)	n	Mean recovery (percent)	RSD (percent)	n	Mean recovery (percent)	RSD (percent)	n	Mean recovery (percent)	RSD (percent)	n	Mean RPD (percent)	Mean SD
cn112012	11/20/2012	22	<LRL	10	97.0	2.3	4	98.9	2.7	6	87.0	12.70	6	7.7	6.5
cn121412	12/14/2012	14	<LRL	6	99.4	1.6	3	104.2	3.6	4	101.9	10.61	4	2.6	2.7
cn020213	02/02/2013	14	<LRL	6	107.5	1.5	3	106.1	0.7	4	93.2	12.88	4	0.8	0.5
cn031213	03/12/2013	12	<LRL	5	101.3	0.8	4	100.2	2.6	2	86.4	2.67	3	2.2	1.0
cn040313	04/03/2013	18	<LRL	8	99.9	2.3	4	107.3	1.2	4	102.3	4.21	5	4.8	8.8
cn050113	05/01/2013	18	<LRL	8	99.8	0.4	4	102.8	1.3	4	96.8	1.84	5	0.9	0.9
cn052413	05/24/2013	18	<LRL	8	99.6	0.8	4	102.5	0.2	4	96.6	0.51	5	1.5	2.2
cn070113	07/01/2013	18	<LRL	8	99.8	0.3	4	114.1	1.0	4	100.1	1.45	5	1.2	0.7
cn070313	07/03/2013	18	<LRL	8	100.6	0.6	4	116.5	1.6	4	100.8	3.19	5	1.8	1.8
cn073013	07/30/2013	18	<LRL	8	99.6	0.6	4	102.6	1.5	4	98.9	1.33	5	1.5	0.6
cn080213	08/02/2013	14	<LRL	6	100.8	0.3	3	102.9	1.4	4	99.1	0.62	4	1.5	1.6
cn091713	09/17/2013	18	<LRL	8	99.5	0.3	4	104.3	0.1	4	99.2	0.35	5	0.8	0.4

Table 5. Surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-In, polyaluminum chloride treated inlet water; Al-Out, polyaluminum chloride treated outlet water; C*x*, wetland cell number; Co-In, untreated control inlet water; Co-Out, untreated control outlet water; E, estimated; Fe-In, ferric sulfate treated inlet water; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not applicable; nd, not determined; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L, MDL for total mercury-particulates=0.059 ng/L, MDL for monomethyl mercury-particulate=0.01 ng/L, MDL for dissolved organic carbon=0.03 mg/L, LRL for dissolved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
			Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Control samples							
C1-Co-In-Nov	11/13/2012	380600121391701	0.94	0.28	0.16	0.05	8.5
C1-Co-In-Dec	12/11/2012	380600121391701	1.70	1.49	0.24	<0.04	26.7
C1-Co-In-Jan	01/22/2013	380600121391701	1.64	0.60	0.30	<0.03	26.0
C1-Co-In-Feb	02/25/2013	380600121391701	1.62	0.77	0.35	nd	23.0
C1-Co-In-Mar	03/26/2013	380600121391701	2.02	0.86	0.36	<0.05	17.3
C1-Co-In-Apr	04/23/2013	380600121391701	2.00	0.79	0.37	0.07	13.0
C1-Co-In-May	05/20/2013	380600121391701	1.62	0.59	0.30	<0.05	10.6
C1-Co-In-Jun	06/25/2013	380600121391701	1.17	0.71	0.25	0.09	7.9
C1-Co-In-Jul	07/22/2013	380600121391701	1.64	1.29	0.42	0.19	10.1
C1-Co-In-Sep	09/03/2013	380600121391701	1.67	1.03	0.88	0.24	8.9
C6-Co-In-Nov	11/13/2012	380557121391701	0.96	0.27	0.21	<0.04	9.3
C6-Co-In-Dec	12/11/2012	380557121391701	1.51	0.38	0.24	<0.04	26.4
C6-Co-In-Jan	01/22/2013	380557121391701	1.78	0.60	0.35	<0.04	26.0
C6-Co-In-Feb	02/25/2013	380557121391701	1.67	0.59	0.37	0.05	22.9
C6-Co-In-Mar	03/26/2013	380557121391701	1.79	0.80	0.41	<0.05	17.5
C6-Co-In-Apr	04/23/2013	380557121391701	2.05	0.86	0.36	0.07	12.9
C6-Co-In-May	05/20/2013	380557121391701	1.49	0.59	0.49	0.06	10.4
C6-Co-In-Jun	06/25/2013	380557121391701	1.20	0.49	0.27	0.09	8.3
C6-Co-In-Jul	07/22/2013	380557121391701	1.25	1.27	0.42	nd	10.1
C6-Co-In-Sep	09/03/2013	380557121391701	1.64	1.09	0.82	0.24	9.0
C9-Co-In-Nov	11/13/2012	380555121391801	*13.91	0.31	0.20	<0.05	8.8
C9-Co-In-Dec	12/11/2012	380555121391801	1.43	0.30	0.24	<0.04	25.0
C9-Co-In-Jan	01/22/2013	380555121391801	1.75	0.55	0.33	<0.04	26.3
C9-Co-In-Feb	02/25/2013	380555121391801	2.47	0.74	0.39	nd	23.1
C9-Co-In-Mar	03/26/2013	380555121391801	1.87	0.82	0.38	E0.06	17.1
C9-Co-In-Apr	04/23/2013	380555121391801	2.01	0.83	0.35	0.07	13.4
C9-Co-In-May	05/20/2013	380555121391801	1.46	0.48	0.25	0.06	10.0
C9-Co-In-Jun	06/25/2013	380555121391801	1.23	0.63	0.27	0.09	8.2
C9-Co-In-Jul	07/22/2013	380555121391801	1.51	1.30	0.43	0.20	10.0
C9-Co-In-Sep	09/03/2013	380555121391801	1.66	1.10	0.77	0.22	9.3

Table 5. Surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.—Continued

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-In, polyaluminum chloride treated inlet water; Al-Out, polyaluminum chloride treated outlet water; C*x*, wetland cell number; Co-In, untreated control inlet water; Co-Out, untreated control outlet water; E, estimated; Fe-In, ferric sulfate treated inlet water; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not applicable; nd, not determined; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L, MDL for total mercury-particulates=0.059 ng/L, MDL for monomethyl mercury-particulate=0.01 ng/L, MDL for dissolved organic carbon=0.03 mg/L, LRL for dissolved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
			Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Control samples—Continued							
C1-Co-Out-Nov	11/13/2012	380600121391901	1.05	0.48	0.37	<0.04	8.9
C1-Co-Out-Dec	12/11/2012	380600121391901	1.29	0.25	0.29	<0.04	28.0
C1-Co-Out-Jan	01/22/2013	380600121391901	1.54	0.46	0.34	<0.03	24.5
C1-Co-Out-Feb	02/25/2013	380600121391901	1.74	0.47	0.39	nd	24.7
C1-Co-Out-Mar	03/26/2013	380600121391901	2.63	1.04	1.00	E0.06	19.4
C1-Co-Out-Apr	04/23/2013	380600121391901	2.05	1.05	1.00	0.13	17.8
C1-Co-Out-May	05/20/2013	380600121391901	1.75	0.40	0.82	0.11	12.6
C1-Co-Out-Jun	06/25/2013	380600121391901	1.44	0.64	0.64	0.14	11.8
C1-Co-Out-Sep	09/03/2013	380600121391901	0.96	0.31	0.32	0.05	11.4
C6-Co-Out-Nov	11/13/2012	380557121391901	1.00	0.18	0.22	<0.04	8.5
C6-Co-Out-Dec	12/11/2012	380557121391901	1.12	0.20	0.25	<0.04	25.6
C6-Co-Out-Jan	01/22/2013	380557121391901	1.26	0.25	0.14	<0.04	25.3
C6-Co-Out-Feb	02/25/2013	380557121391901	1.32	0.22	0.22	<0.03	23.8
C6-Co-Out-Mar	03/26/2013	380557121391901	1.94	0.46	0.68	<0.05	21.2
C6-Co-Out-Apr	04/23/2013	380557121391901	2.00	0.66	0.87	0.10	19.9
C6-Co-Out-May	05/20/2013	380557121391901	1.60	0.46	0.78	0.08	12.6
C6-Co-Out-Jun	06/25/2013	380557121391901	1.71	0.75	0.47	0.09	14.3
C6-Co-Out-Jul	07/22/2013	380557121391901	1.33	0.40	0.42	0.07	13.8
C6-Co-Out-Sep	09/03/2013	380557121391901	0.89	0.23	0.24	<0.03	11.7
C9-Co-Out-Nov	11/13/2012	380555121391901	0.84	<0.19	0.13	<0.03	8.5
C9-Co-Out-Dec	12/11/2012	380555121391901	1.09	<0.17	0.15	<0.03	27.2
C9-Co-Out-Jan	01/22/2013	380555121391901	1.33	0.38	0.17	<0.03	24.0
C9-Co-Out-Feb	02/25/2013	380555121391901	1.39	0.27	0.27	<0.03	24.9
C9-Co-Out-Mar	03/26/2013	380555121391901	1.84	0.81	0.40	<0.04	15.1
C9-Co-Out-Apr	04/23/2013	380555121391901	2.07	1.11	0.71	0.15	16.9
C9-Co-Out-May	05/20/2013	380555121391901	2.10	0.43	1.30	0.14	11.9
C9-Co-Out-Jun	06/25/2013	380555121391901	1.75	0.94	0.94	0.23	11.4
C9-Co-Out-Jul	07/22/2013	380555121391901	1.49	0.37	0.70	nd	13.1
C9-Co-Out-Sep	09/03/2013	380555121391901	1.03	0.33	0.37	<0.07	11.5

Table 5. Surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.—Continued

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-In, polyaluminum chloride treated inlet water; Al-Out, polyaluminum chloride treated outlet water; C*x*, wetland cell number; Co-In, untreated control inlet water; Co-Out, untreated control outlet water; E, estimated; Fe-In, ferric sulfate treated inlet water; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not applicable; nd, not determined; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L, MDL for total mercury-particulates=0.059 ng/L, MDL for monomethyl mercury-particulate=0.01 ng/L, MDL for dissolved organic carbon=0.03 mg/L, LRL for dissolved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
			Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Polyaluminum chloride treated samples							
C3-Al-In-Nov	11/13/2012	na	0.25	1.07	0.08	0.20	2.1
C3-Al-In-Dec	12/11/2012	na	0.47	1.84	0.15	<0.14	8.0
C3-Al-In-Jan	01/22/2013	na	0.59	1.20	0.16	0.12	8.9
C3-Al-In-Feb	02/25/2013	na	0.47	1.93	0.15	0.18	7.7
C3-Al-In-Mar	03/26/2013	na	0.45	1.97	0.16	0.28	4.3
C3-Al-In-Apr	04/23/2013	na	0.71	1.92	0.12	0.29	2.9
C3-Al-In-May	05/20/2013	na	0.38	1.72	0.10	0.21	3.0
C3-Al-In-Jun	06/25/2013	na	0.27	1.33	0.10	0.29	2.0
C3-Al-In-Jul	07/22/2013	na	0.41	2.38	0.19	nd	2.9
C3-Al-In-Sep	09/03/2013	na	0.53	2.62	0.46	0.51	2.3
C4-Al-In-Nov	11/13/2012	na	0.62	1.81	0.08	<0.12	2.2
C4-Al-In-Dec	12/11/2012	na	0.54	1.35	0.15	<0.15	9.0
C4-Al-In-Jan	01/22/2013	na	0.49	1.65	0.15	0.11	9.1
C4-Al-In-Feb	02/25/2013	na	0.60	2.19	0.16	0.22	7.1
C4-Al-In-Mar	03/26/2013	na	0.47	2.33	0.11	0.33	4.2
C4-Al-In-Apr	04/23/2013	na	0.60	3.82	0.11	0.39	2.9
C4-Al-In-May	05/20/2013	na	0.54	1.57	0.10	0.24	3.2
C4-Al-In-Jun	06/25/2013	na	0.35	1.03	0.10	0.30	2.1
C4-Al-In-Jul	07/22/2013	na	0.43	2.21	0.16	0.46	4.0
C4-Al-In-Sep	09/03/2013	na	0.53	2.65	0.37	0.76	2.4
C8-Al-In-Nov	11/13/2012	na	0.30	1.18	0.10	0.23	2.3
C8-Al-In-Dec	12/11/2012	na	0.49	1.08	0.11	0.13	9.5
C8-Al-In-Jan	01/22/2013	na	0.47	1.68	0.15	<0.12	8.8
C8-Al-In-Feb	02/25/2013	na	0.60	2.42	0.15	nd	7.1
C8-Al-In-Mar	03/26/2013	na	0.42	2.42	0.14	E0.30	4.2
C8-Al-In-Apr	04/23/2013	na	0.50	2.50	0.12	0.30	2.9
C8-Al-In-May	05/20/2013	na	0.37	1.62	0.11	0.21	3.1
C8-Al-In-Jun	06/25/2013	na	0.31	1.30	0.09	0.30	2.3
C8-Al-In-Jul	07/22/2013	na	0.41	2.18	0.19	0.43	2.8
C8-Al-In-Sep	09/03/2013	na	0.60	2.91	0.41	0.64	2.5

Table 5. Surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.—Continued

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-In, polyaluminum chloride treated inlet water; Al-Out, polyaluminum chloride treated outlet water; C*x*, wetland cell number; Co-In, untreated control inlet water; Co-Out, untreated control outlet water; E, estimated; Fe-In, ferric sulfate treated inlet water; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not applicable; nd, not determined; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L, MDL for total mercury-particulates=0.059 ng/L, MDL for monomethyl mercury-particulate=0.01 ng/L, MDL for dissolved organic carbon=0.03 mg/L, LRL for dissolved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
			Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Polyaluminum chloride treated samples—Continued							
C3-Al-Out-Nov	11/13/2012	na	0.26	<0.08	<0.04	<0.02	3.3
C3-Al-Out-Dec	12/11/2012	na	0.35	<0.12	0.04	<0.04	10.4
C3-Al-Out-Jan	01/22/2013	na	0.58	0.16	0.15	<0.04	10.4
C3-Al-Out-Feb	02/25/2013	na	0.44	0.14	E0.06	<0.02	9.5
C3-Al-Out-Mar	03/26/2013	na	0.67	<0.22	0.09	0.09	5.9
C3-Al-Out-Apr	04/23/2013	na	0.71	0.26	0.25	0.06	4.5
C3-Al-Out-May	05/20/2013	na	0.72	0.15	0.32	<0.04	4.3
C3-Al-Out-Jun	06/25/2013	na	0.95	0.35	0.54	0.18	4.2
C3-Al-Out-Jul	07/22/2013	na	0.70	0.35	0.48	0.06	3.8
C3-Al-Out-Sep	09/03/2013	na	0.45	0.14	0.20	<0.04	2.8
C4-Al-Out-Nov	11/13/2012	na	0.24	<0.09	0.04	<0.04	3.4
C4-Al-Out-Dec	12/11/2012	na	0.44	0.23	0.12	<0.05	10.4
C4-Al-Out-Jan	01/22/2013	na	0.49	0.12	0.12	<0.03	9.9
C4-Al-Out-Feb	02/25/2013	na	0.54	0.16	0.14	<0.03	9.7
C4-Al-Out-Mar	03/26/2013	na	0.61	0.23	0.11	<0.03	6.3
C4-Al-Out-Apr	04/23/2013	na	0.64	0.34	0.29	0.07	5.2
C4-Al-Out-May	05/20/2013	na	0.72	0.17	0.30	<0.03	4.7
C4-Al-Out-Jun	06/25/2013	na	0.94	0.46	0.50	<0.12	5.2
C4-Al-Out-Jul	07/22/2013	na	0.84	0.51	0.48	nd	4.5
C4-Al-Out-Sep	09/03/2013	na	0.78	0.30	0.43	0.07	4.2
C8-Al-Out-Nov	11/13/2012	na	0.29	<0.13	0.08	<0.02	3.8
C8-Al-Out-Dec	12/11/2012	na	0.47	<0.19	0.12	<0.04	11.8
C8-Al-Out-Jan	01/22/2013	na	0.48	<0.12	0.11	<0.03	9.5
C8-Al-Out-Feb	02/25/2013	na	0.59	<0.10	0.22	<0.02	9.8
C8-Al-Out-Mar	03/26/2013	na	0.58	<0.22	0.11	<0.04	5.8
C8-Al-Out-Apr	04/23/2013	na	0.59	0.39	0.22	0.11	5.6
C8-Al-Out-May	05/20/2013	na	0.75	0.25	0.40	0.06	4.3
C8-Al-Out-Jun	06/25/2013	na	0.79	0.43	0.39	0.08	4.2
C8-Al-Out-Jul	07/22/2013	na	0.62	0.18	0.28	0.07	3.3
C8-Al-Out-Sep	09/03/2013	na	0.51	0.26	0.29	0.05	3.0

Table 5. Surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.—Continued

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-In, polyaluminum chloride treated inlet water; Al-Out, polyaluminum chloride treated outlet water; C*x*, wetland cell number; Co-In, untreated control inlet water; Co-Out, untreated control outlet water; E, estimated; Fe-In, ferric sulfate treated inlet water; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not applicable; nd, not determined; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L, MDL for total mercury-particulates=0.059 ng/L, MDL for monomethyl mercury-particulate=0.01 ng/L, MDL for dissolved organic carbon=0.03 mg/L, LRL for dissolved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
			Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Ferric sulfate samples							
C2-Fe-In-Nov	11/13/2012	na	0.69	1.76	0.09	0.21	1.2
C2-Fe-In-Dec	12/11/2012	na	0.38	2.21	0.10	<0.14	6.6
C2-Fe-In-Jan	01/22/2013	na	0.47	2.29	0.12	0.13	7.8
C2-Fe-In-Feb	02/25/2013	na	0.53	2.17	0.14	0.23	7.4
C2-Fe-In-Mar	03/26/2013	na	0.51	2.76	0.12	0.26	4.9
C2-Fe-In-Apr	04/23/2013	na	0.64	2.40	0.13	0.26	3.9
C2-Fe-In-May	05/20/2013	na	0.52	2.11	0.15	0.23	2.8
C2-Fe-In-Jun	06/25/2013	na	0.43	1.60	0.12	0.30	2.9
C2-Fe-In-Jul	07/22/2013	na	0.38	3.03	0.12	0.49	2.3
C2-Fe-In-Sep	09/03/2013	na	0.61	2.80	0.40	0.74	2.7
C5-Fe-In-Nov	11/13/2012	na	0.26	1.83	0.12	<0.17	1.2
C5-Fe-In-Dec	12/11/2012	na	0.37	2.26	0.10	E0.18	6.7
C5-Fe-In-Jan	01/22/2013	na	0.53	1.64	0.11	0.19	7.0
C5-Fe-In-Feb	02/25/2013	na	0.55	2.50	0.14	0.24	8.0
C5-Fe-In-Mar	03/26/2013	na	0.52	2.31	0.12	E0.27	4.9
C5-Fe-In-Apr	04/23/2013	na	0.64	2.35	0.15	0.27	4.0
C5-Fe-In-May	05/20/2013	na	0.41	1.81	0.10	0.27	2.7
C5-Fe-In-Jun	06/25/2013	na	0.48	<0.34	0.13	0.11	2.9
C5-Fe-In-Jul	07/22/2013	na	0.35	2.46	0.13	0.45	2.2
C5-Fe-In-Sep	09/03/2013	na	0.58	2.59	0.40	0.68	2.8
C7-Fe-In-Nov	11/13/2012	na	0.23	1.55	0.14	0.22	1.2
C7-Fe-In-Dec	12/11/2012	na	0.35	1.99	E0.06	E0.18	6.7
C7-Fe-In-Jan	01/22/2013	na	0.59	2.36	E0.06	0.17	7.3
C7-Fe-In-Feb	02/25/2013	na	0.56	3.07	0.15	nd	7.8
C7-Fe-In-Mar	03/26/2013	na	0.54	2.29	0.18	<0.10	4.8
C7-Fe-In-Apr	04/23/2013	na	0.59	2.50	0.16	0.28	4.2
C7-Fe-In-May	05/20/2013	na	0.54	1.78	0.08	0.24	2.5
C7-Fe-In-Jun	06/25/2013	na	0.51	1.63	0.13	0.28	2.9
C7-Fe-In-Jul	07/22/2013	na	0.35	2.60	0.14	0.50	2.2
C7-Fe-In-Sep	09/03/2013	na	1.06	2.59	0.43	0.73	2.9

Table 5. Surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon, Twitchell Island, California, November 2012–September 2013.—Continued

[All mercury analyses performed at U.S. Geological Survey Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** Al-In, polyaluminum chloride treated inlet water; Al-Out, polyaluminum chloride treated outlet water; C*x*, wetland cell number; Co-In, untreated control inlet water; Co-Out, untreated control outlet water; E, estimated; Fe-In, ferric sulfate treated inlet water; Fe-Out, ferric sulfate treated outlet water; ID, identification; LRL, laboratory reporting limit; MDL, method detection limit; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; na, not applicable; nd, not determined; ng/L, nanograms per liter; <, less than. The MDL for total mercury-filtered and monomethyl mercury-filtered=0.04 ng/L, MDL for total mercury-particulates=0.059 ng/L, MDL for monomethyl mercury-particulate=0.01 ng/L, MDL for dissolved organic carbon=0.03 mg/L, LRL for dissolved organic carbon=0.3 mg/L]

Sample ID	Date (mm/dd/yyyy)	Station ID	Total mercury		Monomethyl mercury		Dissolved organic carbon (mg/L)
			Filtered (ng/L)	Particulate (ng/L)	Filtered (ng/L)	Particulate (ng/L)	
Ferric sulfate samples—Continued							
C2-Fe-Out-Nov	11/13/2012	na	0.34	<0.14	<0.04	<0.03	4.7
C2-Fe-Out-Dec	12/11/2012	na	0.71	<0.25	0.05	<0.07	10.7
C2-Fe-Out-Jan	01/22/2013	na	0.50	0.37	<0.04	<0.04	9.1
C2-Fe-Out-Feb	02/25/2013	na	0.55	1.66	0.07	nd	11.3
C2-Fe-Out-Mar	03/26/2013	na	0.52	0.17	<0.04	<0.04	6.8
C2-Fe-Out-Apr	04/23/2013	na	0.75	0.61	0.14	0.10	9.4
C2-Fe-Out-May	05/20/2013	na	0.66	0.34	0.11	0.04	7.8
C2-Fe-Out-Jun	06/25/2013	na	0.89	0.64	0.16	0.07	9.8
C2-Fe-Out-Sep	09/03/2013	na	0.42	0.28	0.13	0.07	3.6
C5-Fe-Out-Nov	11/13/2012	na	0.60	0.61	0.23	<0.04	4.2
C5-Fe-Out-Dec	12/11/2012	na	0.65	0.59	0.23	E0.05	11.8
C5-Fe-Out-Jan	01/22/2013	na	0.47	0.45	0.07	<0.03	9.5
C5-Fe-Out-Feb	02/25/2013	na	0.52	0.79	0.12	0.05	11.3
C5-Fe-Out-Mar	03/26/2013	na	0.95	0.70	0.18	<0.04	13.8
C5-Fe-Out-Apr	04/23/2013	na	1.12	0.69	0.38	0.10	17.0
C5-Fe-Out-May	05/20/2013	na	0.93	1.10	0.35	0.11	10.3
C5-Fe-Out-Jun	06/25/2013	na	1.17	*6.47	0.44	0.15	9.9
C5-Fe-Out-Jul	07/22/2013	na	0.72	0.59	0.21	nd	12.4
C5-Fe-Out-Sep	09/03/2013	na	0.54	0.40	0.12	0.05	8.8
C7-Fe-Out-Nov	11/13/2012	na	0.26	0.15	0.06	<0.02	3.9
C7-Fe-Out-Dec	12/11/2012	na	0.28	0.18	<0.04	<0.04	9.1
C7-Fe-out-Jan	01/22/2013	na	0.45	0.23	E0.04	<0.04	8.3
C7-Fe-Out-Feb	02/25/2013	na	0.45	0.36	0.08	<0.03	9.6
C7-Fe-Out-Mar	03/26/2013	na	0.87	<0.23	<0.04	<0.03	8.3
C7-Fe-Out-Apr	04/23/2013	na	0.86	0.73	0.24	0.08	10.3
C7-Fe-Out-May	05/20/2013	na	0.67	0.35	0.21	0.05	8.9
C7-Fe-Out-Jun	06/25/2013	na	0.69	0.73	0.19	<0.05	7.2
C7-Fe-Out-Jul	07/22/2013	na	0.59	0.52	0.09	0.07	7.2
C7-Fe-Out-Sep	09/03/2013	na	0.46	0.49	0.10	<0.07	6.6

*Value is atypically high for this treatment and location.

Dissolved Organic Carbon Concentration

Dissolved organic carbon concentrations in all 10 blanks were less than the LRL of 0.3 mg/L (table 1), and the 10 field-replicate RPDs had a mean of less than 4 percent (table 2). A total of 202 laboratory-blank samples were analyzed along with the DOC samples for the study; there were no laboratory-blank detections greater than the LRL of 0.3 mg/L (table 4). Two standard reference materials (SRMs) were used: the caffeine (Sigma Aldrich, St. Louis, Missouri) standard was prepared to contain 1.0 mg/L of carbon, and potassium hydrogen phthalate (KHP) was prepared to contain 3.0 mg/L of carbon. The mean recovery of 45 caffeine samples was 105.2 percent, with a mean SD of 1.5 percent, and the mean recovery of 89 KHP SRMs was 100.4 percent, with a mean SD of 1.0 percent. The matrix spike consisted of 2.0 mg/L of carbon as KHP, and the mean recovery of 48 matrix spike samples was 96.9 percent, with a mean SD of 4.4 percent. A total of 56 laboratory duplicate samples were analyzed and had a mean RPD of 2.3 percent, with a mean relative SD of 2.3 percent.

Surface-Water Results

Measured surface-water concentrations of THg, MeHg, and DOC are presented in table 5, except for those from control-outlet 1 and iron-outlet 2 during July 2013, when there was no flow at these sites. Filtered and particulate data for each sample were summed to obtain total values for both THg and MeHg. In cases where either the filtered or the particulate data were missing, no total value was calculated for the sample. Two sample results had atypically high values compared to the mean values. The November 13, 2012, sample for control-inlet 9 had a THg-F concentration of 13.91 ng/L, and the June 25, 2013, sample for iron-treatment outlet 5 had a THg-P concentration of 6.47 ng/L (table 5). Ranges of THg concentrations without these atypically high measurements are presented in table 6 along with the ranges of MeHg and DOC concentrations. These two values were also excluded from the time-series graphs showing the mean and standard deviation for THg-F, THg–P, THg, MeHg-F, MeHg-P, MeHg, and DOC concentrations in water from each wetland-cell treatment (iron, aluminum, control) by site (inlet, outlet; figs. 2, 3).

Excluding the atypically high values, THg-F in water ranged from 0.94 to 2.47 ng/L at the control inlets and from 0.84 to 2.63 ng/L at the control outlets (table 6), and THg-P concentrations in water ranged from 0.27 to 1.49 ng/L at the control inlets and from 0.17 to 1.11 ng/L at the control outlets. The MeHg-F concentrations in water ranged from 0.16 to 0.88 ng/L at the control inlets and from 0.13 to 1.30 ng/L at the control outlets; the MeHg-P concentrations in water ranged from 0.03 to 0.24 ng/L at the control inlets and from 0.03 to 0.23 ng/L at the control outlets. The DOC concentrations in water ranged from 7.9 to 26.7 mg/L at the control inlets and from 8.5 to 28.0 mg/L at the control outlets (table 6).

Median values and the first and third quartiles (25th, 75th) for THg, MeHg, and DOC are shown in table 6 along with maximum and minimum values. In the control-wetland cells, the median THg-F concentrations were 1.64 ng/L (1.46, 1.78) in water from the inlets and 1.44 ng/L (1.12, 1.75) from the outlets; the median THg-P concentrations were 0.72 ng/L (0.56, 0.86) in water from the inlets and 0.39 ng/L (0.25, 0.64) from the outlets. In the control-wetland cells, the median MeHg-F concentrations were 0.35 ng/L (0.26, 0.41) in water from the inlets and 0.39 ng/L (0.25, 0.71) from the outlets; the median MeHg-P concentrations were 0.06 ng/L (0.04, 0.09) in water from the inlets and 0.05 ng/L (0.04, 0.09) from the outlets. The median DOC concentrations were 11.78 mg/L (9.28, 22.94) in water from the inlets and 15.12 mg/L (11.81, 24.00) from the outlets.

The percentage of decrease in THg, MeHg, and DOC concentrations relative to the source water was calculated for each sampling date by using the following equation:

$$\frac{[C]s - [C]x}{[C]s} \times 100 \quad (1)$$

where

$[C]s$ is the mean concentration in source water (control inlet, three samples), and

$[C]x$ is the concentration in water for each treatment and sampling site.

Negative values, therefore, represent an increase in constituent concentration relative to source water. The mean and standard deviation of constituent concentration decreases in samples from the three replicated wetlands by treatment and sampling site relative to the source water are shown in figures 4 and 5. Because residence time through the cells ranged from 2 to 10 days, the percentage of change between the source water and water at the outflow sites is a first approximation.

Relative to the untreated source water, the inlet samples for the coagulation-treatment wetland cells showed coagulation effectively transferred mercury and carbon from the dissolved fraction to the particulate fraction of water: filtered THg was decreased by 59–76 percent, filtered MeHg by 40–70 percent, and DOC by 65–86 percent (table 7).

Table 6. Ranges and medians of surface-water concentrations of mercury, monomethyl mercury, and dissolved organic carbon in the inlet and outlet water of the experimental-wetland cells, Twitchell Island, California, November 2012–September 2013.

[All mercury analyses performed at U.S. Geological Survey, Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey, California Water Science Center Organic Matter Research Laboratory. **Abbreviations:** mg/L, milligrams per liter; ng/L, nanograms per liter]

Treatment	Site	Total mercury, filtered				Total mercury, particulate				Total mercury, filtered+particulate			
		Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	25th, 75th percentile (ng/L)	Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	25th, 75th percentile (ng/L)	Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	25th, 75th percentile (ng/L)
Control	Inlet	0.94	*2.47	*1.64	1.46, *1.78	0.27	1.49	0.72	0.56, 0.86	1.22	*3.21	*2.39	1.94, *2.79
Control	Outlet	0.84	2.63	1.44	1.12, 1.75	0.17	1.11	0.39	0.25, 0.64	1.03	3.67	1.86	1.51, 2.46
Aluminum	Inlet	0.25	0.71	0.47	0.41, 0.54	1.03	3.82	1.88	1.41, 2.37	1.32	4.42	2.41	1.92, 2.79
Aluminum	Outlet	0.24	0.95	0.59	0.47, 0.72	0.09	0.51	0.22	0.14, 0.29	0.33	1.40	0.80	0.63, 0.98
Iron	Inlet	0.23	1.06	0.52	0.39, 0.58	0.35	3.07	2.29	1.81, 2.50	0.83	3.65	2.79	2.32, 3.05
Iron	Outlet	0.26	1.17	0.60	0.47, 0.75	0.14	*1.66	*0.47	0.28, *0.65	0.41	*2.21	*1.06	0.86, *1.37

Treatment	Site	Monomethyl mercury, filtered				Monomethyl mercury, particulate				Monomethyl mercury, filtered+particulate			
		Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	25th, 75th percentile (ng/L)	Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	25th, 75th percentile (ng/L)	Minimum (ng/L)	Maximum (ng/L)	Median (ng/L)	25th, 75th percentile (ng/L)
Control	Inlet	0.16	0.88	0.35	0.26, 0.41	0.03	0.24	0.06	0.04, 0.09	0.21	1.12	0.39	0.32, 0.45
Control	Outlet	0.13	1.30	0.39	0.25, 0.71	0.03	0.23	0.05	0.04, 0.09	0.16	1.44	0.44	0.28, 0.86
Aluminum	Inlet	0.08	0.46	0.15	0.10, 0.16	0.11	0.76	0.26	0.17, 0.31	0.20	1.13	0.39	0.27, 0.44
Aluminum	Outlet	0.04	0.54	0.21	0.11, 0.32	0.02	0.18	0.04	0.03, 0.07	0.06	0.72	0.24	0.15, 0.36
Iron	Inlet	0.06	0.43	0.13	0.11, 0.15	0.10	0.74	0.24	0.18, 0.28	0.23	1.16	0.38	0.29, 0.42
Iron	Outlet	0.04	0.44	0.12	0.06, 0.21	0.02	0.15	0.05	0.04, 0.07	0.07	0.59	0.17	0.09, 0.25

Treatment	Site	Dissolved organic carbon			
		Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	25th, 75th percentile (mg/L)
Control	Inlet	7.92	26.66	11.78	9.28, 22.94
Control	Outlet	8.51	27.99	15.12	11.81, 24.00
Aluminum	Inlet	2.03	9.53	3.04	2.45, 7.11
Aluminum	Outlet	2.82	11.83	4.92	4.17, 9.53
Iron	Inlet	1.17	8.02	3.44	2.67, 6.66
Iron	Outlet	3.64	17.00	9.14	7.22, 10.34

*One value for total mercury-filtered (13.91 ng/L) and one value for total mercury-particulate (6.47 ng/L), identified in table 1 as atypically high for that site and location, were excluded from these calculations.

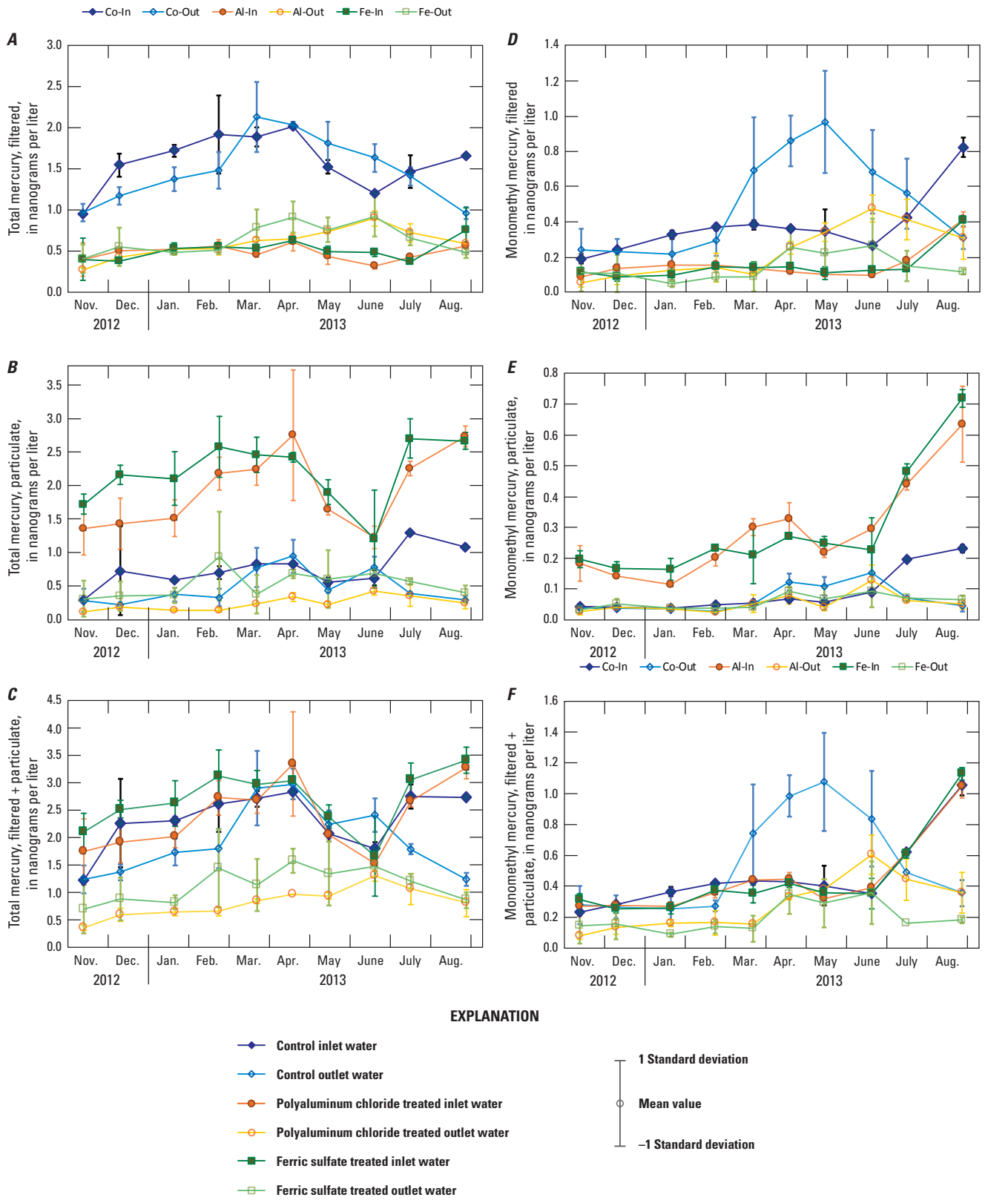

Figure 2. Mean and standard deviation of mercury and monomethyl mercury concentrations in water from three replicated experimental-wetland cells, November 2012–September 2013, Twitchell Island, California: *A*, filtered total mercury (THg-F); *B*, particulate total mercury (THg-P); *C*, sum of filtered and particulate total mercury; *D*, filtered monomethyl mercury; *E*, particulate monomethyl mercury; and *F*, sum of filtered and particulate monomethyl mercury. One value for THg-F and one value for THg-P, identified in table 1 as atypically high for that site, were excluded from the mean and standard deviation calculations and from these figures.

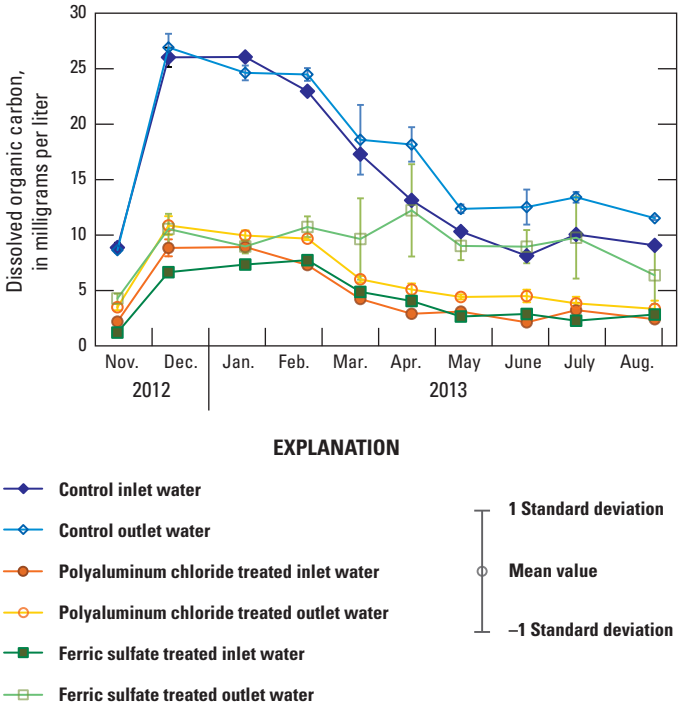

Figure 3. Mean and standard deviation of dissolved organic carbon concentration in water from three replicated experimental-wetland cells, Twitchell Island, California, November 2012–September 2013.

Changes in THg, MeHg, and DOC concentrations due to wetland passage varied both by treatment and by season (figs. 2–5). In the control during the winter months (November–March), there was little change in DOC concentration, but during the spring and summer months (April–September), the DOC concentrations increased over 20 percent (figs. 3, 5). During these months, the DOC concentrations also increased in the treated-wetland cells, particularly those treated with iron sulfate; however, DOC concentrations in the outlet-water samples were still lower than or similar to the untreated source water. Similarly, THg-F (figs. 2*A*, 4*A*) and MeHg-F (figs. 2*D*, 4*D*) concentrations generally increased during passage through the wetland cells during the spring and summer months (April–July). The greatest increases in MeHg-F were measured in the control cells, followed by the polyaluminum-chloride treated wetland cells, and the lowest increases in MeHg-F were in the iron-sulfate treated cells. In contrast, for all 10 sampling dates, concentrations of THg-P (figs. 2*B*, 4*B*) and MeHg-P (figs. 4*B*, 4*E*) in water decreased during passage through the wetland cells that received coagulant treatments (table 7).

Despite net production of THg-F and MeHg-F during wetland passage in spring and summer, overall, the coagulation-wetland systems decreased THg (filtered plus particulate) concentrations relative to source water (figs. 2*C*, 4*C*; table 7) and also decreased or had little effect on MeHg (filtered plus particulate) concentrations relative to source water (figs. 2*F*, 4*F*; table 7). The one exception to this was on June 25, 2013, when MeHg concentrations in the outflow water of the polyaluminum-chloride treatment were greater than in the untreated source water (on average, 0.60 compared to 0.35 ng/L, respectively, table 1).

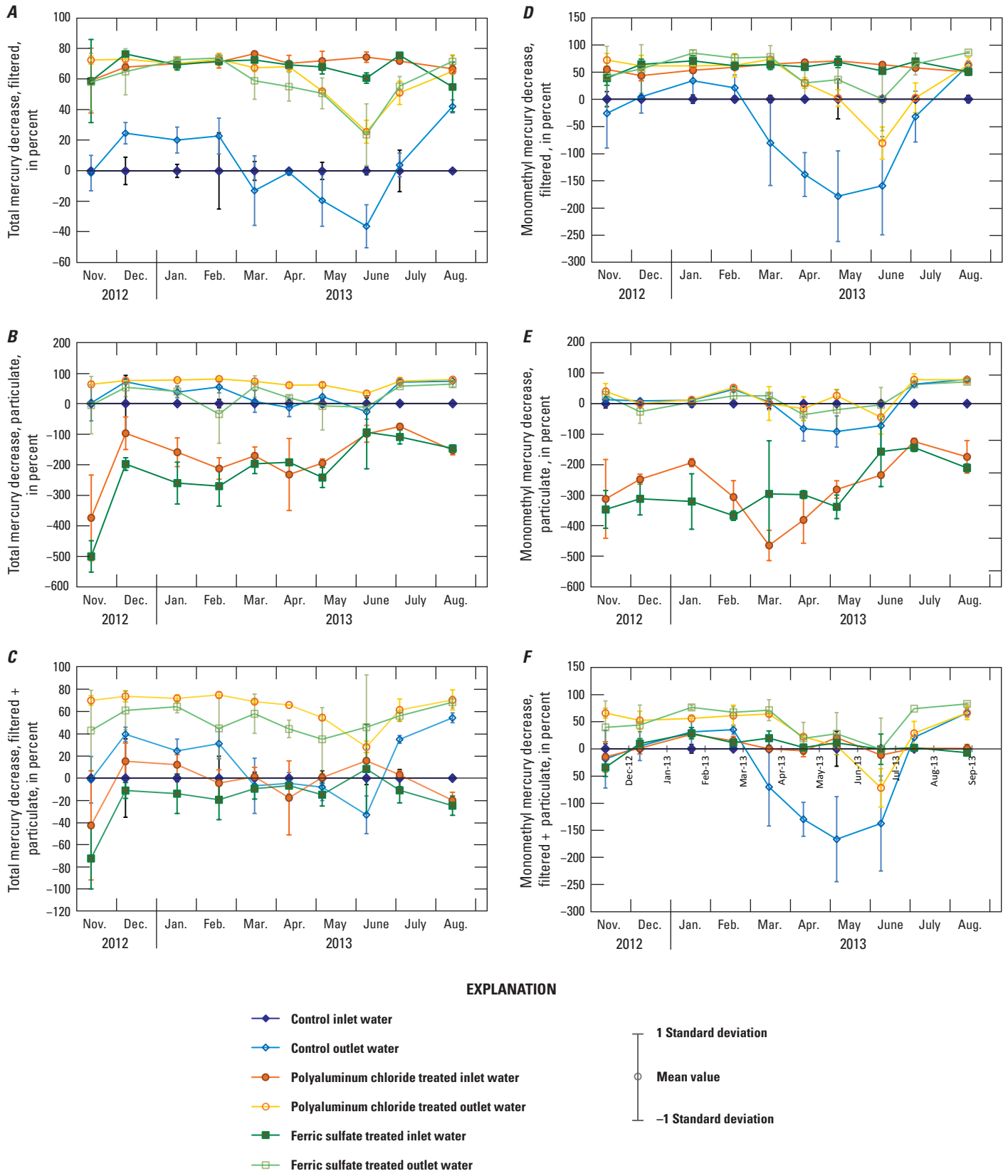

Figure 4. Mean and standard deviation of the percentage of decrease in mercury and monomethyl mercury concentrations in water from three replicated experimental-wetland cells compared to source water, November 2012–September 2013, Twitchell Island, California: *A*, filtered total mercury (THg-F); *B*, particulate total mercury (THg-P); *C*, sum of filtered and particulate total mercury; *D*, filtered monomethyl mercury; *E*, particulate monomethyl mercury; and *F*, the sum of filtered and particulate monomethyl mercury. One value for THg-F and one value for THg-P, identified in table 1 as atypically high for that site, were excluded from the percent decrease calculations and from these figures.

Table 7. Ranges and medians of the percentage decrease of mercury, monomethyl mercury, and dissolved organic carbon concentrations relative to source water in experimental-wetland cells, Twitchell Island, California, November 2012–September 2013.

[All mercury analyses performed at U.S. Geological Survey, Wisconsin Mercury Research Laboratory. All dissolved organic carbon analyses performed at U.S. Geological Survey, California Water Science Center Organic Matter Research Laboratory.]

Treatment	Site	Total mercury, filtered				Total mercury, particulate				Total mercury, filtered+particulate			
		Minimum	Maximum	Median	25th, 75th percentile	Minimum	Maximum	Median	25th, 75th percentile	Minimum	Maximum	Median	25th, 75th percentile
Control	Outlet	–36.1	*42.1	*1.4	–9.99, *22.1	–26.9	73.0	29.8	3.26, 50.2	–33.0	54.3	11.5	–6.34, 33.9
Aluminum	Inlet	58.9	76.4	70.6	68.3, 71.7	–375	–75.2	–169	–208, –155	–42.5	15.6	1.1	3.24, 9.81
Aluminum	Outlet	25.6	72.8	67.6	55.3, 71.7	32.8	80.5	67.7	60.5, 76.0	28.0	74.8	69.3	62.4, 71.4
Iron	Inlet	58.6	76.3	69.2	65.0, 72.2	–535	–94.5	–220	–268, –159	–58.2	8.2	–12.6	–18.3, –9.89
Iron	Outlet	23.6	73.6	58.3	55.1, 69.7	–34.7	*63.4	*8.9	–7.13, *51.8	18.7	68.3	50.4	43.2, 60.2

Treatment	Site	Monomethyl mercury, filtered				Monomethyl mercury, particulate				Monomethyl mercury, filtered+particulate			
		Minimum	Maximum	Median	25th, 75th percentile	Minimum	Maximum	Median	25th, 75th percentile	Minimum	Maximum	Median	25th, 75th percentile
Control	Outlet	–252	62.3	–29.3	–124, 16.6	–91.2	80.0	10.1	–52.7, 38.5	–226	66.2	–7.0	–115, 28.7
Aluminum	Inlet	43.1	67.6	58.0	53.4, 63.1	–464	–124	–264	–311, –203	–14.9	26.8	0.8	–2.8, 2.36
Aluminum	Outlet	–81.0	73.0	61.2	9.18, 62.6	–44.4	78.5	19.6	0.16, 49.5	–71.8	66.2	54.2	23.9, 63.4
Iron	Inlet	38.6	70.4	60.6	53.7, 63.8	–396	–144	–316	–344, –242	–34.3	28.7	2.2	–8.49, 10.7
Iron	Outlet	0.0	85.8	60.1	32.8, 77.0	–36.3	72.0	15.6	–15.4, 28.0	–0.9	82.8	55.5	24.3, 73.3

Treatment	Site	Dissolved organic carbon			
		Minimum	Maximum	Median	25th, 75th percentile
Control	Outlet	–54.0	5.5	–13.7	–31.8, –4.20
Aluminum	Inlet	65.7	77.9	71.7	68.0, 75.0
Aluminum	Outlet	44.6	65.2	60.9	58.0, 61.8
Iron	Inlet	64.6	86.4	71.8	68.9, 74.4
Iron	Outlet	–10.1	65.6	37.0	8.35, 52.9

*One value for total mercury-filtered (13.91 nanograms per liter (ng/L)) and one value for total mercury-particulate (6.47 ng/L), identified in table 1 as atypically high for that site and location, were excluded from these calculations.

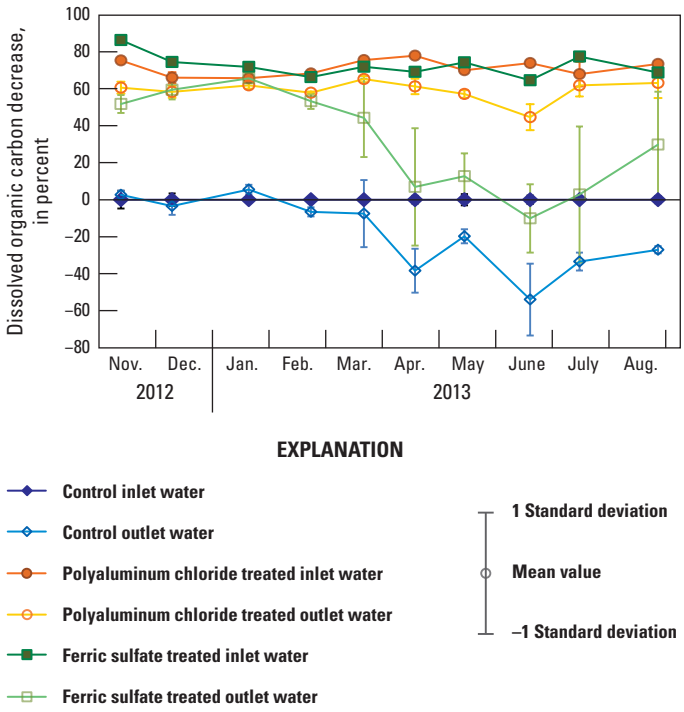

Figure 5. Mean and standard deviation of the percentage decrease in dissolved organic carbon concentrations in water from experimental-wetland cells compared to source water for November 2012–September 2013, Twitchell Island, California.

Summary

Nine experimental-wetlands cells were constructed on Twitchell Island, a subsided island in the Sacramento–San Joaquin Delta, to test the effectiveness of using metal-based coagulants to decrease concentrations of dissolved organic carbon (DOC) and mercury (Hg) in water. Each wetland cell received untreated drainage water, drainage water treated with polyaluminum chloride, or drainage water treated with iron sulfate. Following the coagulation treatment, the water passed through the constructed wetland cells to allow particles to settle out of the water. The purpose of this report is to present total mercury (THg) and monomethyl mercury (MeHg) concentration data for filtered and suspended-particulate fractions of water, along with DOC concentration data for surface-water samples collected from the inflow and outflow structures of these nine wetland cells.

In the control wetland cells, filtered THg concentrations in water ranged from 0.94 to 2.47 nanograms per liter (ng/L) at the inlets and from 0.84 to 2.63 ng/L at the outlets, and particulate THg in water ranged from 0.27 to 1.49 ng/L at the inlets and from 0.17 to 1.11 ng/L at the outlets. The filtered MeHg concentrations in water ranged from 0.16 to 0.88 ng/L at the control inlets and from 0.13 to 1.30 ng/L at the control outlets; particulate MeHg concentrations in water ranged from 0.03 to 0.24 ng/L at the control inlets and from 0.03 to 0.23 ng/L at the control outlets. DOC concentrations in water ranged from 7.9 to 26.7 milligrams per liter (mg/L) at the control inlets and from 8.5 to 28.0 mg/L at the control outlets.

Following coagulation but prior to passage through the wetland cells, coagulation treatments transferred mercury and carbon from the dissolved fraction into the particulate fraction of water relative to the untreated source water. The coagulation treatments decreased filtered THg, filtered MeHg, and DOC concentrations in water by 59–76 percent, 40–70 percent, and 65–86 percent, respectively. Passage through the wetland cells decreased the particulate fraction of mercury in treatments that received coagulated water. Changes in THg, MeHg, and DOC concentrations wetland passage varied both by treatment and by season. Despite net production of MeHg-F during wetland passage between April and July, the coagulation-wetland systems generally decreased THg (filtered plus particulate) and MeHg (filtered plus particulate) concentrations relative to source water.

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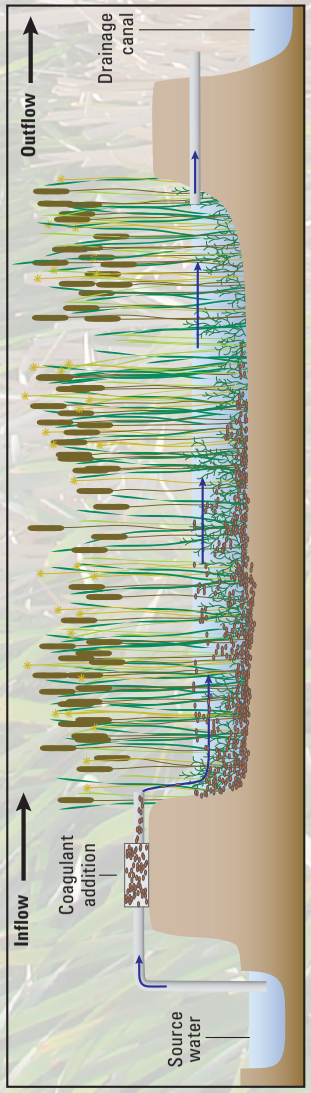

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